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Abstract

A statistical model is constructed describing spot freight rates in terms of the operating costs of the marginal ship, the size of the various vessels relative to the marginal ship, the proportion of the tanker fleet operating in the spot market and the proportion of the fleet which is laid up for more than two months. The model is tested over the entire period from September 1971 to December 1976, and also over shorter periods characterized by either abnormally high or abnormally low rates. Based on these results, a measure of the economies of scale for tankers of different sizes is developed, and the proportion of these economies which is enjoyed by the shipowner, under various market conditions, is calculated. The findings generally verify the underlying theoretical postulates.

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*This paper is based on the first author's thesis entitled "Transportation Costs and Oil Prices" which was submitted in partial fulfillment of the requirements for the Master's degree in Management at the Massachusetts Institute of Technology in February 1978, and the second author's continuing research in short-term and long-term tanker rates.

I. INTRODUCTION

The demand for tanker capacity is derived from the world demand for oil. The ocean tanker is the only meaningful means for oil transportation between countries separated by oceans, and the future demand for crude oil is the most important investment consideration for the tanker owner.

Because of this, and in a world where oil prices are fixed by a monopolistic cartel and pricing decisions are inextricably mixed with politics, one may conclude that conditions favoring administered pricing schemes would be prevalent also in the tanker markets. If this were the case, a model describing freight rates purely in terms of demand for oil would, most probably, exhibit a large variance and, consequently, be of limited predictive value.

For several reasons, the tanker markets do not behave like the oil markets. It was pointed out elsewhere (Zannetos 1966; 1973; 1975) that for theoretical and institutional considerations we observe in the tanker markets behavior resembling perfect competition. As a result, fluctuations in the demand for oil which may not necessarily affect oil prices may cause significant changes in the structure and level of tanker rates.

The experience of the last few years, shows that, in the short run, the aggregate demand for oil is highly price inelastic. In spite of this, fluctuations in the aggregate demand for oil do occur for seasonal reasons, causing in turn fluctuations in the demand for ocean transportation. But, and even if the aggregate demand for oil were to be constant, shifts in the liftings of crude oils from one country to another are not unusual. A decrease in the crude shipments of one country and even if it is exactly offset by an increase from another country, will affect available tanker capacity if the transportation intensity of the two crudes to a given

given destination is different. Short of a period long enough for shipbuilding, the supply of tankers beyond a certain level close to full capacity is also highly inelastic. Finally, the size composition of the tanker fleet must be considered fixed in the short run, although it has been changing over the years as more VLCCs (Very Large Crude Carriers) and ULCCs (Ultra Large Crude Carriers) entered into the market.

These observations led to the construction of a model which attempts to describe the level and structure of the prevailing single-voyage freight rates in terms of the short-term quantifiable characteristics of the tanker markets. The purpose of this model is not so much to predict what future spot rates will or ought to be as to evaluate empirically the relative significance of market parameters and, in particular, the effect of tanker size in the process of spot-rate formation. This is believed to be of considerable value as far as decision making is concerned, because, as long as these empirical relationships hold, tanker owners, after evaluating the characteristics of future states of the tanker market will be able to determine for each scenario the relevant spot rates and thus be better guided in their long-term investment decisions. The economies of scale accruing to tankers of large size, can easily be calculated as well as the proportion of these economies which must be conceded to the charterers as compensation for decreased flexibility, under various market conditions. In the short run the model will also be of considerable assistance to the decision making of both tanker owners and charterers, in that it will provide information on the normal rate for a vessel under the prevailing market conditions.

II. NECESSARY THEORETICAL NOTIONS

A. The Spot Market

The main purpose of the spot market for tankers is to satisfy unforeseen short-term increases in the aggregate demand for oil. It also satisfies predictable fluctuations, such as seasonal, in the demand facing the oil companies. If the covariations of these fluctuations between oil companies are negative, then the fluctuation in the total demand is less than the sum of the absolute individual fluctuations. Under such conditions, the total transportation capacity that is required to accommodate the requirements of the oil industry will be less, if the oil companies depend on the spot market to take care of fluctuations around their expected individual requirements, than the case where each firm tries to provide for its maximum requirements. Tankers, therefore, are chartered and relet for single or consecutive voyages.

Although the spot market on the average provides employment for approximately only 15 percent of the world's total tonnage, it is far more important than this percentage indicates because it influences expectations about the present and future market conditions. When the level of spot rates goes outside a "range of strict static relevance" (Zannetos, 1966) it significantly affects the level of time-charter rates. The latter once fixed, extend over the duration of the time charter.

Another long-term impact of the spot market is reflected in the shipbuilding backlog. It has been shown by Tinbergen (1934, in Klaasen Ed. 1959), Koopmans (1939) and Zannetos (1966; 1977) that orders for

new vessels and spot rates are dynamically interdependent. Zannetos went a step further to link spot rates and price-elastic expectations, and the latter to orders for new vessels, placed with a lag of about six months from peak to peak. He also determined the conditions under which stable market equilibria may be observed in the tanker markets and the dynamic process by which the level of spot rates is established. The consequence of the work of the above to the present discussion in that the spot rate may not only affect the future level and structure of rates but also sets things in motion which generate cyclical price behavior within both the tanker transportation and the tankship building markets without the necessity for cyclical demand.

Since it carries only a small percentage of the total tonnage, the spot market is very volatile. The supply schedule of tanker capacity is, short of a period long enough for shipbuilding, very inelastic beyond full capacity, but very elastic at its lower part because of the refusal rate of the various vessels as these become marginal at the various levels of demand. This change from elasticity to inelasticity occurs within less than two percentage points of total capacity, and indicates that "a shift in the demand by as little as one percent around the critical area will be enough to create fortunes or disaster" (Zannetos, 1966). An increase of one percent in the demand for tonnage is further magnified in the spot market where it will comprise on the average more than 6 percent of the capacity already operating there. A slightly larger increase in demand may be enough to send spot rates to soaring heights. For these reasons, the proportion of the tanker fleet operating in the spot market may serve as a barometer of the market conditions.

At any point in time a small proportion of the tanket fleet is out of the market, for maintenance and repairs. During periods of high rates, maintenance and repairs are expedited or even postponed wherever that is possible and, therefore, idle capacity is minimal. When rates are low, on the other hand, the maintenance period is normally extended. This and other withdrawals in readiness from the market create a large idle capacity which is not laid up. The proportion of the total capacity which is idle in readiness or for repairs and maintenance would, therefore, supplement the proportion of capacity operating in the spot market as an indicator of the level of freight rates.

B. The Significance of the Marginal Vessel

The tanker market, as pointed out, is one of the few markets in which almost perfectly competitive conditions prevail. Ownerships of tankers, even by anyone of the largest independent companies, is a small fraction of the total capacity. The mobility of capital, the ease of entry into the market, the absence of large administrative and financial optima which permit the vessel to operate as a firm and the absence of excessive artificial controls, all contribute to the perfectly competitive climate (Zannetos, 1966).

In a market which is governed by the uncontrolled interaction of supply and demand, the price at any moment in time is determined by the then available marginal capacity (Zannetos 1966; 1975). Similarly, freight rates must be at a level such that the marginal capacity will be able to earn its marginal cost, otherwise it will not enter the market. For the long run, this rate will be the applicable average full cost which includes a market-determined return on investment.

In the short run, however, one may observe freight rates which are below the operating costs of the particular marginal vessels and yet the vessels may not refuse employment at those rates. The reason for this seemingly paradoxical behavior is that the alternatives to employment are (a) tie up, which involves certain costs, or (b) scrappage which is irreversible. If, therefore, the owners of the marginal vessel expect a recovery from the low rates, in a reasonable time, they will be better off to operate for awhile at rates which do not fully cover the out-of-pocket costs of their vessels.

Another seeming paradox emerges when one compares the weighted spot rate, time adjusted, which is applicable to a given size of a vessel over its life time, with the rate which will enable the owner to recover his investment and realize the necessary market return. Sometimes the former is lower than the latter, and the reason for this is that most vessels enter the spot market after a lengthy and profitable time charter. In the case of most marginal vessels, by the time they reach that stage of their economic life they would have earned enough to liquidate the initial loan. As a result, the owners of these vessels are willing to keep them operating as long as the rate is expected to cover their out-of-pocket costs and leave something for the owner. Those shipowners, who are risk prone and prefer to operate in the spot market exclusively will, of course, suffer if the rates are low when their new vessels are delivered from the shipyards. And if the depressed market conditions continue for any length of time, default of the loans and eventual bankruptcy may occur. In the recent years those who placed orders for new tankers as a result of the upsurge in spot rates to Worldscale 450 in October 1973, and did not secure time

charters in advance, went through some very critical times and some of them did not survive.

When the spot rates are low and the then marginal vessels barely cover their operating costs, larger vessels because of economies of large size, are able to earn a very good return at that same rate. For this reason, and in order to provide an inducement to the charterers to shoulder the inflexibility of large size, most of the economies accruing to size are conceded to the charterers.

III. THE MODEL

The model consists of a non-linear combination of four variables which define S_t^n, the spot freight rate for a given size of vessel n at time t. The choice of explanatory variables has been made following an extensive study of the characteristics of the tanker markets and the formation of short-term rates as described by Zannetos (1966). A brief outline of the underlying theory has been provided in the previous section and for a thorough rendition the reader is advised to consult the aforementioned references.

The variables used in the model which we will test are defined as follows:

(a) R_t^m : the operating costs of the marginal vessel m at time t.

(b) X_1 : percent of working fleet operating in the spot market.

(c) X_2 : the ratio of the capacity of a given vessel to that of the marginal vessel at time t, expressed as a percentage.

(d) X_3 : the tanker tonnage laid up as a proportion (to the nearest thousand DWT) of the total tanker fleet tonnage at time t.

The spot rate S_t^n for a given size n of a vessel at time t, is then defined as:

$$S_t^n = K \cdot R_t^m \cdot X_1^a \cdot X_2^b \cdot X_3^c \qquad (1)$$

where K is a constant, and a, b, and c are exponents.

This model was applied to the actual spot market transactions reported between September 1971 and December 1976. This period contains one complete cycle of spot rates. In order to detect possible changes in the relative significance of the independent variables, the model was tested under various market conditions over the rate cycle. Existing theory tells us that such changes should be observed. (Zannetos 1966; 1975; 1977).

The transactions used were those reported monthly by H. P. Drewry (2) for the Persian Gulf - U.K./ Continent route. The latter route was chosen because more oil flows between these two geographic areas than over any other single route. Besides, the existence of proper ancillary facilities at most loading and unloading ports on that route make possible the chartering of vessels of all sizes, which is necessary for analyzing the structure of rates. Information with regard to the proportion of the world's tanker fleet operating in the spot market and the proportion of the fleet laid up for two months or more, was obtained from the same source.

The definition of what constitutes a marginal vessel is fundamental not only to the understanding of the model but also to its application. The marginal class of vessels cannot refer to the smallest vessels operating in the markets because these vessels are mostly used for special purposes, such as for transporting oil to isolated harbors which are not equipped to handle larger vessels. As a result, the

definition of "marginal capacity", for spot-rate purposes, must be based on the smallest size class operating in the major crude-trade routes in normal periods. Furthermore, the marginal size class has to be a substantial proportion (between 5 and 10 percent) of the capacity operating in the spot market, otherwise it will not be influential in setting the structure of the rates.

Starting with the above definition of the marginal size class, the size distribution of tankers operating in the Persian Gulf - U.K./Continent route was examined, to determine what size classes constituted a significant proportion of total available capacity at the various points in time. The analysis showed that the marginal-size class for the last four months of 1971 was in the 45,000 - 54,999 DWT range, that of 1972 and 1973 was in the 55,000 - 64,999 DWT range for 1974 and 1975 was in the 75,000 - 99,999 DWT range and for 1976 the marginal class was in the 100,000 - 149,999 DWT range. The size of the marginal vessel in each case was taken as the mid-point of the marginal class.

Information on operating costs of tankers is scarce. Attempts to obtain recent cost figures have not been successful because tanker operators consider their cost data confidential and hesitate to release them to outsiders. For the purposes of the present study the cost data used were obtained from Polemis (4), and are based on actual figures and forecasts provided by respectable tanker operators, tanker brokers and the U. S. Maritime Administration. Table 1 shows the operating costs of the marginal vessel during the period under consideration.

Table 1. Operating Costs of the Marginal Vessel

Year	DWT	Out of Pocket Costs		Fuel Costs	Port Charges	Total Operating Costs
		$/DWT Month	$/DWT/ Trip	$/DWT/ Trip	$/DWT/ Trip	$/DWT/Trip
1971	50,000	1.2359	2.7515	1.7240	0.1358	4.6113
1972	60,000	1.1808	2.6289	1.5913	0.1247	4.3449
1973	60,000	1.3346	2.9713	1.9203	0.1247	5.0163
1974	87,000	1.1555	2.5725	4.2340	0.1043	6.9108
1975	87,000	1.4858	3.3079	4.4216	0.1043	7.8338
1976	125,000	1.3376	2.9780	3.5959	0.0905	6.6644

The out of pocket costs consist of:

(a) Crew wages and salaries

(b) Subsistence costs and supplies

(c) Insurance

(d) Maintenance and repairs, and

(e) Miscellaneous costs

All these costs, together with fuel costs and port charges are paid by the owner of the vessel when it operates in the spot market.

IV. APPLICATION OF THE MODEL

The model we have just described was applied and its coefficients were evaluated using the actual single voyage fixtures, 1630 in all, from September 1971 to December 1976.

Several versions of the general model were tested, but one gave consistently better results than the rest. This version is a logarithmic regression equation with the ratio of the spot rate of the n^{th} vessel divided by the operating costs of the marginal vessel, as the dependent variable, and the percent of the working fleet operating in the spot market (X_1), the size ratio of the chartered vessel to that

of the marginal vessel (X_2) and the proportion of the total tanker tonnage laid up (X_3) as the explanatory variables.

In applying the model, certain problems of positive serial correlation were encountered. This is believed to be the result of many factors, the most important of which are:

(a) The length of the time period over which the marginal vessel was kept constant. In the present application, the size of the marginal vessel was chosen to represent the market conditions over a calendar year after examining the spot transactions that have taken place during that year. In periods of rapidly increasing or rapidly decreasing rates the size of the marginal vessel is expected to change many times within a year. By taking an average for the year, we tend to overestimate the size when rates are increasing and underestimate it when rates are decreasing. Because of this averaging we also expect our model to underestimate the rates at the peak of the cycle and overestimate these at the trough. An obvious refinement will be achieved by determining the marginal vessel from monthly or even weekly transactions, especially during periods of highly fluctuating rates.

(b) The time period between consecutive measurements of the proportion of the tanker fleet operating in the spot market and the proportion of the tanker fleet which is laid up. These parameters are revised monthly. However, in many cases, often near the critical range, these proportions may change 2 or 3 percentage points from one month to the next. Since even a one percentage movement, up or down, in the critical range of the proportion of the fleet operating in the spot market is enough to bring fortune or disaster to shipowners, shortening the period between consecutive measurements of these parameters is likely

to bring about substantial improvement in the performance of the model. This task, however, is expected to be very difficult and laborious in the absence of published weekly statistics.

(c) The price-elastic expectations and the induced interperiod substitutions which prevail in the tanker markets during periods of abnormally high or abnormally low rates (Zannetos 1966, 1975, 1977).

In order to reduce the serial correlation, the regressions were run using the Cochrane - Orcutt Iterative technique. (See D. Cochrane and G. H. Orcutt 1949). This approach suggests that an initial estimate of p, the first order serial coefficient, be made using ordinary least squares regression. Then:

(i) all the data are transformed by p (e.g. $X_t - p\ X_{t-1}$)

(ii) a regression is run on the transformed data

(iii) the regression coefficients are multiplied into the original dependent variables to recalculate the serially correlated errors.

(iv) a new estimate of p is formed, and a new iteration begins.

(v) when p changes by less than 0.005 from one iteration to the next, the iteration terminates and a regression output is produced.

The results of the statistical analysis are shown in Table 2. When the Cochrane-Orcutt technique is used, the Durbin-Watson statistic and the coefficient of determination (R^2) are calculated from the residuals of the regression on the transformed variables. In all regression equations the dependent variable is the natural logarithm of the ratio of the spot rate to the operating costs of the marginal

vessel, at time t, expressed as a percentage, i.e.

$$Y = \frac{S_t^n}{R_t^m} \times 100\% \qquad (2)$$

Part A of Table 2 shows the results of the application of the model on the data of the entire period under consideration. Despite the inherent volatility of spot freight rates and the relative lack of refinement in the construction of the data base, two aspects on which we commented previously, the fit is reasonably good. All the explanatory variables are highly significant and their coefficients have the sign predicted by the theory. The spot rate for a vessel in question decreases with an increase in (a) the percentage of the tanker fleet operating in the spot market, (b) the size of the vessel relative to the marginal vessel, and (c) the percentage of the fleet which is laid up. Of the three explanatory variables X_1 (the percentage of fleet operating in the spot market) seems to be the most important.

Practically no collinearity exists between the independent variables. A more serious problem is, evidently, the existence of positive serial correlation, shown by the Durbin-Watson (DW) statistic. The Cochrane-Orcutt technique corrects that to a great extent as seen in the regression of the transformed data. The general relationships observed in the ordinary least squares regression are preserved and become even stronger, with R increasing from .828 to .955 and R^2, the coefficient of determination, increasing from .6858 to .9127.

<u>Table 2</u> <u>Results of the Regression Analysis</u>

A. Regression with 1630 observations from September 1971 to December 1976.

(a) Ordinary Least Squares

$$\ln (Y) = 10.4781 - 1.1167 \ln (X_1) - 0.2778 \ln (X_2) - 0.3887 \ln (X_3)$$

t-statistics (79.493) (-34.209) (-13.533) (-36.587)

$R = 0.828$ $R^2 = 0.6858$ $DW = 0.3042$

(b) Cochrane-Orcutt Iterative Technique

$$\ln (Y) = 9.4755 - 0.7762 \ln (X_1) - 0.2487 \ln (X_2) - 0.4037 \ln (X_3)$$

t-statistics (34.122) (-7.775) (-25.991) (10.697)

$R = 0.955$ $R^2 = 0.9127$ $DW = 2.6146$ $p = 0.86$

B. Regression with 1122 observations from September 1971 to December 1972 and from December 1973 to December 1976.

(a) Ordinary Least Squares

$$\ln (Y) = 8.8248 - 0.6225 \ln (X_1) - 0.3512 \ln (X_2) - 0.2404 \ln (X_3)$$

t-statistics (76.269) (-22.744) (-20.033) (-27.755)

$R = 0.789$ $R^2 = 0.6223$ $DW = 0.5866$

(b) Cochrane-Orcutt Iterative Technique

$$\ln (Y) = 8.4822 - 0.5614 \ln (X_1) - 0.3152 \ln (X_2) - 0.2420 \ln (X_3)$$

t-statistics (41.942) (-8.865) (-27.789) (-11.509)

$R = 0.901$ $R^2 = 0.8127$ $DW = 2.4826$ $p = 0.713$

C. Regression with 508 observations from January 1973 to November 1973.

(a) Ordinary Least Squares

$$\ln (Y) = 6.8176 - 0.8096 \ln (X_1) - 0.1744 \ln (X_2) + 0.8671 \ln (X_3)$$

t-statistics (17.527) (-8.994) (-5.958) (9.119)

$R = 0.586$ $R^2 = 0.3436$ $DW = 0.4316$

(b) Cochrane-Orcutt Iterative Technique

$$\ln (Y) = 7.0466 - 0.7687 \ln (X_1) - 0.1031 \ln (X_2) + 0.5540 \ln (X_3)$$

t-statistics (8.458) (-3.356) (-6.115) (2.398)

$R = 0.870$ $R^2 = 0.7567$ $DW = 2.4024$ $p = 0.800$

D. Regression with 168 observations uring 1975

(a) Ordinary Least Squares

$$\ln(Y) = 11.3705 - 1.0191 \ln(X_1) - 0.5582 \ln(X_2) - 0.3813 \ln(X_3)$$

t-statistics (11.547) (-5.339) (-15.768) (-3.930)

$R = 0.786$ $R^2 = 0.6179$ $DW = 1.300$

(b) Cochrane-Orcutt Iterative Technique

$$\ln(Y) = 11.3157 - 1.0038 \ln(X_1) - 0.5442 \ln(X_2) - 0.3941 \ln(X_3)$$

t-statistics (8.394) (-3.790) (-16.500) (-2.872)

$R = 0.815$ $R^2 = 0.6648$ $DW = 2.138$ $p = 0.352$

E. Regression with 235 observations from June 1973 to November 1973

(a) Ordinary Least Squares

$$\ln(Y) = 5.5873 - 0.3664 \ln(X_1) - 0.2057 \ln(X_2) + 1.0869 \ln(X_3)$$

t-statistics (10.3223) (-3.631) (-4.973) (6.630)

$R = 0.537$ $R^2 = 0.2881$ $DW = 0.691$

(b) Cochrane-Orcutt Iterative Technique

$$\ln(Y) = 6.1224 - 0.4422 \ln(X_1) - 0.0968 \ln(X_2) + 0.6878 \ln(X_3)$$

t-statistics (5.844) (-1.956) (-3.153) (2.076)

$R = 0.783$ $R^2 = 0.6128$ $DW = 2.380$ $p = 0.700$

The results of the first attempt to test the model under various market conditions are given in part B of Table 2. The two periods considered here are characterized by low rates, generally less than Worldscale 80. Comparing these results with those for the entire period, we observe the increased significance of size under conditions of low rates. This is reflected in the magnitude of the coefficient of $\ln(X_2)$ in the regression equation which is equal to -0.3152 for the period of low rates while it equals -0.2487 for the entire cycle. We also notice the decrease significance of X_1 and X_3. As is well known,given the form of the model we are using,these coefficients represent the elasticity of the dependent variable with respect to the explanatory variables.

Part C of Table 2 represents the results of the regression for a period of relatively high rates. During this period spot rates were generally higher than Worldscale 80. A significant difference between these results

and those presented earlier for the period of low rates, is the existence of a positive correlation between the proportion of the fleet laid up and the level of spot rates. This reversal of sign in the relationship is one of the asymmetries which theoretically is to be expected, and is associated with the particular cause and effect relationship that exists between these two variables. The explanation is that, during low rates, the proportion of the fleet laid up is an effect of the depressed rates. Small vessels are withdrawn from the market, maintenance and repairs are protracted, waiting for a recovery, and in order to avoid excessive losses due to permanent lay up or idleness in readiness. This gives rise to the negative correlation. When rates fall, as a result of a decrease in the demand for oil or an increase in the tanker fleet capacity, the proportion of the total tonnage laid up increases. As rates increase and the utilization of the fleet approaches full capacity, more and more small, inefficient and old ships enter the market, all ships sail at full steam and repairs and maintenance are postponed. Up to this point the negative relationship still holds. The reversal of the relationship and the new role of X_3 as a cause of higher rates appears a few months later. Because of the increased wear due to the higher speed, the postponed, hasty or inadequate maintenance, the use of older tankers and the possible increase in the number of accidents, due to denser traffic, some ships withdraw from the market for repairs. Such withdrawals of capacity at the inelastic part of the supply schedule cause the rates to go up even further. Hence the positive correlation.

The regression equation for this period, though all the coefficients are highly significant, does not explain the movement of rates as well as it does for the entire period or for periods of low rates. The value of the coefficient of determination (R^2) is only half that for the entire period,

when ordinary least squares are used and still considerably lower when the Cochrane-Orcutt technique is used. An important result, however, can be observed by comparing the regression equation of part C of Table 2 with those of part B. The elasticity of Y with respect to X_2 is much smaller when the level of freight rates is high than at low rates. During periods of high rates, there is scarcity of tonnage and, therefore, the risks for unemployment or underemployment do not exist, especially in the short run. The owners of large vessels do not have to concede much to encourage the charterers and, as a result, enjoy the economies of scale accruing to their vessels almost to the full extent. These findings give support to the theoretical arguments.

The last two parts (D and E) of Table 2 are intended to give a closer look at the differences in the process of rate formation between periods of high and low rates. Table 2-D shows the results for 1975, a period of very depressed spot rates, generally below Worldscale 50. On the other hand, Table 2-E shows the results for a period of very high spot rates, higher than Worldscale 150. Qualitatively, the results are consistent with those of parts B and C respectively. As for the quantitative measurements, the asymmetric behavior of X_3 is accentuated and the difference in the elasticity of Y with respect to X_2 between periods of low and high rates, is further reinforced.

V. ESTIMATION OF ECONOMIES OF SCALE

The quantification of the effect of vessel size on spot rates, under different market conditions, facilitates the estimation of the proportion of the economies of scale which are enjoyed by the owners of large vessels and that which is conceded to the charterers. These

rate concessions determine the structure of spot rates around a level determined by the relevant costs (depending on market conditions) of the then marginal transportation capacity. Since the proportions of the economies of scale conceded do not remain constant but depend on the general market climate, we can only estimate them during discrete time intervals, under more-or-less steady conditions. Also, as we have already explained, in order that these numbers be meaningful they should represent the economies of scale relative to the marginal vessel operating in the market during the period under consideration.

Zannetos (1966) explained theoretically and provided empirical support to his theoretical arguments that the most likely states or regions of stable equilibria of spot rates are at: (1) rates far above the long-run economic cost of the marginal vessel and (2) rates at/or below the out-of-pocket cost of the marginal vessel. In other words the spot-rate equilibria are to be found in regions either excessively above those dictated by the long-run supply schedule of the industry or excessively below. For this reason, we will estimate the economies of scale and the proportions, thereof, enjoyed by the owner and the charterer during discrete periods at each of these two states. Another period, however, which is thought to yield results representative of the longer term will also be considered. But first we will produce a workable definition of the economies of scale and the relative proportions of such that remain with the owners.

In order to define the economies of scale and calculate the relevant proportions we must first identify the relevant costs which should be used. As it has been explained, the basis of the rate level, especially

during periods of low rates, is the marginal cost of the marginal ship. For a tanker operator who is in the spot market, whether after a long period on time charter or not, the main consideration in the short run is the coverage of the operating costs of his vessel. For this reason, in the formulation only operating costs will be considered.

We define the total economies of scale accruing to a vessel at any point in time as the difference between the contribution margin of the given vessel and that of the marginal vessel, assuming that both realize the same spot rate. If one were to use a "per ton of capacity" measure the economies of scale for a given vessel n will be the difference between the short-run operating costs per ton of capacity of the marginal vessel m and those of vessel n. For minor computational reasons and because of the estimation of other variables in the formulation, however, we found it easier to work with total contribution margins.

Although most vessels enter the spot market after the major part of the initial investment has been paid back, in the general formulation we must define a common factor on the basis of which future net cash inflows of vessels of different sizes may be made directly comparable, and also take care of the fact that larger vessels achieve a slightly better payload per DWT than smaller vessels. This factor may be the level of the initial investment. Since, generally, the shipbuilding cost of a vessel of size 2n is less than the cost of two vessels of size n each, we define a variable, which we will call "marginal vessel equivalent", E_n, such that,

$$E_n = \frac{\text{Total shipbuilding cost of vessel, size n, at time t}}{\text{Total shipbuilding cost of the marginal vessel at time t}}$$

It should be noted that the size of the marginal ship is determined with respect to a reference period and not the period when the order was placed. For the purposes of the present analysis it is assumed that ships were ordered two to four years before the period when their operating costs and revenues are considered. This may appear to contradict our previous assertion that there is normally a long interval between the building of a vessel and its entry into the spot market. Since, however, both the total economies of scale and the proportion of these that is enjoyed by the owner of a vessel of size n, are not constant but vary with time, our analysis aims at introducing and illustrating a method of short-run measurement rather than calculating a "universal constant". Furthermore, the relationship between shipbuilding costs of large and small vessels does not remain constant over the tanker-rate cycle, and as a result the "most recent" experience of tanker owners tends to influence their decisions much more than the distant past. It must be stressed again that the factor E_n is not intended to account for the "recovery of the initial investment", which is a sunk cost. It is used as a surrogate for equating the short-run opportunity costs of the respective investments and for those dimensions of short-run efficiency of the large vessels (such as carrying capacity) which are not reflected in simple DWT ratios or in absolute operating costs.

Using the notation of section III and additional parameters defined below we will now develop formulae for the total economies of scale and the proportions of these enjoyed by the owners and the charterers. Let,

$(DWT)_n$ = capacity in dead-weight-tons of the n^{th} vessel

$(DWT)_m$ = capacity in dead-weight-tons of the marginal vessel for the period under consideration

R_t^n = the operating costs of a vessel, size n, at time t per DWT

S_t^m = the spot rate per ton of oil delivered for the marginal vessel at time t, estimated by the regression equation of Y against X_1, X_2, and X_3, as per Equation (1). We assume here that carrying capacity is approximated by DWT.

A fixed level of investment, I, for a given base period, would enable a shipowner to purchase either one vessel of capacity $(DWT)_n$ or E_n smaller vessels of capacity $(DWT)_m$. These two alternatives will generate cash flows, when operating in the spot market during some future period, as follows:

Contribution margin (C.M.) of the n^{th} vessel $(C.M.)_n = (S_t^n - R_t^n)\ (DWT)_n$ (3)

E_n marginal vessels $(C.M.)_m = E_n\ (S_t^m - R_t^m)\ (DWT)_m$ (4)

Their difference is

$$\Delta\ (C.M.) = (C.M)_n - E_n (C.M)_m$$

$$= (S_t^n - R_t^n)\ (DWT)_n - E_n\ (S_t^m - R_t^m)\ (DWT)_m \qquad (5)$$

The contribution margin of the n^{th} vessel if it realize the same spot rate as the marginal vessel during the same period is

$$(C.M.)_{n/m} = (S_t^m - R_t^n)\ (DWT)_n \qquad (6)$$

The total realizable economies of scale for the n^{th} vessel during the period under consideration is then:

$$(E.S.) = (C.M.)_{n/m} - E_n (C.M)_m$$

$$= (S_t^m - R_t^n)\ (DWT)_n - E_n\ (S_t^m - R_t^m)\ (DWT)_m \qquad (7)$$

$$= S_t^m\ [\ (DWT)_n - E_n (DWT)_m\ ] + R_t^m\ E_n\ (DWT)_m - R_t^n\ (DWT)_n \qquad (8)$$

The proportion of these economies of scale which is enjoyed by the owner of the n^{th} vessel is:

$$(E.S.)_o = \frac{\Delta(C.M.)}{(E.S.)}$$

$$= \frac{(S_t^n - R_t^n)\ (DWT)_n - E_n\ (S_t^m - R_t^m)\ (DWT)_m}{(S_t^m - R_t^n)\ (DWT)_n - E_n\ (S_t^m - R_t^m)\ (DWT)_m} \qquad (9)$$

Since by our previous definition

$$X_2 = \frac{(DWT)_n}{(DWT)_m} \times 100\%$$

the above formula becomes

$$(E.S)_o = \frac{(S_t^n - R_t^n)\ X_2 - 100\ E_n\ (S_t^m - R_t^m)}{(S_t^m - R_t^n)\ X_2 - 100\ E_n\ (S_t^m - R_t^m)} \qquad (10)$$

It follows that the proportion of the economies of scale which is conceded to the charterer is equal to:

$$(E.S.)_c = 1 - (E.S)_o$$

VI. ECONOMIES OF SCALE UNDER HIGH, LOW AND NORMAL SPOT RATES

The economies of scale for ships of various sizes during August 1973, October 1974 and May 1975 were calculated using the formulae of Section V.

During August 1973 spot freight rates had already risen considerably and were still rising. Their level was in the range between WS 250 and WS 300 using the 1973 Worldscale. Later on it climbed to WS 450. Using shipbuilding costs for 1971, as estimated by Polemis (4),

and a marginal vessel size of 60,000 DWT, the proportion of the economies of scale enjoyed by the owners of vessels of various sizes was calculated. The findings were plotted and shown in Figure 1. It can be seen that the shape of the plot is a slightly downward sloping straight line. After an initial drop in the proportion of economies of size remaining with the vessel owner the curve levels off and does not drop below 67% even for ULCCs. The reason for this is that the proportion of economies of scale conceded to the charterer accounts only for the loss of flexibility on his part, because during this period of very high rates and tonnage scarcity the risks for unemployment and underemployment did not exist. It should be noted that the estimation of spot rates for this period was made using the regression equation of part E(b) of Table 2.

In a similar fashion, using the Cochrane-Orcutt regression equation of part D, table 2, and equation (10) the results shown in Figure 2 were obtained for May 1975. The two curves were obtained using shipbuilding costs of two different periods in the past. The month of May 1975 is of particular importance because it is characterized by very depressed spot rates, the lowest that have ever been encountered in the spot market up to that time. In fact, during this period, ships of all sizes were operating at a loss, some of them not even covering the cost of fuel. The lower limit of spot rates during such a period is determined by the marginal costs of the marginal ship less the layup costs and the expected reactivation costs, spread over the expected layup period. In this case the economies of scale represent the reduction in losses relative to the marginal ship if the given vessel realized the spot rate of the marginal ship. The extent to which this loss reduction is realized by the owner,

represents the proportion of the economies of scale that he enjoys, according to our definition. Shipbuilding costs appear to be very significant in the estimation of $(E.S.)_o$ during this period. Since both the level and structure of shipbuilding costs change with time, it is interesting to note that a correct decision taken at some past period, with reference to some future market situation, may prove to be wrong for someone else who made the same decision at a different period, although the reference market conditions may remain the same.

Another important characteristic shown in Figure 2 is the rapidly decreasing proportion of economies of scale enjoyed by the owner of the vessel. The cause of this is as Equation (10) shows, the particular choice of the marginal vessel. In our case, we have chosen for illustration purposes a vessel of 60,000 DWT. The shape of the curve appears to be independent of the year when the shipbuilding order is assumed to have been placed. The substantial concessions that the owner must make to the charterer, which mostly occur for vessels 2-1/2 times as large as the marginal vessel, reflect the increased risk of unemployment and under-employment, on top of the decreased flexibility, that a charterer assumes when chartering a large vessel. The levelling off of the curve above a capacity of approximately 220,000 DWT, for 1975, reflects the fact that the economies of scale realized by the charterer beyond that size exactly match the additional risk and costs of inflexibility involved.

Figure 3 shows the proportion of the economies of scale enjoyed by the owners of vessels of various sizes under the market conditions prevailing in October 1974. During this period 24 percent of the working fleet was operating in the spot market and 1.3 percent was

laid-up. The average spot rate realized by the marginal vessel at that time, estimated by the regression equation of Part A (b), Table 2, was approximately 25 percent above its operating costs. This situation is considered representative of the "normal" long-term market situation where the marginal vessel earns its marginal cost plus a market determined return on investment.

The shape of the graph is very similar to that of Figure 2 showing that even during periods of low, but not depressed, rates, the owner, according to our model, concedes an increasing proportion of the economies of scale in order to induce the charterers to hire a larger vessel. The same levelling-off of the graph, however, is again observed, for vessels above the 220,000 DWT. The time, when the investment decision was made, causes an almost vertical shift of the curve, reflecting the different structures of shipbuilding costs during different periods.

The analysis so far may have created the impression that, the owners of very large vessels may realize lower returns on their investment, because they retain a smaller part of the economies of scale which accrue to their vessels than do the owners of vessels of less than twice the size of the marginal vessel. This, however, is not the case, because the investment required per ton of carrying capacity for vessels of different sizes varies. A simple calculation can verify that although the owners of very large vessels concede a large amount of the economies of scale to the charterers, what they retain enables them to realize a higher return on investment, than if they had invested in smaller vessels. Taking for illustration the market conditions of October 1974 and the shipbuilding costs of 1971 as a representative scenario, we find that the initial investment, the estimated operating costs, the spot rate and

the contribution margin, for a single trip, for a 100,000 DWT and a 300,000 DWT vessel respectively are as follows:

		100,000 DWT	300,000 DWT
1.	Initial Investment, $ m	17.100	36.083
2.	Operating Cost, $/DWT/trip	6.396	4.138
3.	Spot Rate, $/DWT/trip	8.330	6.330
4.	Contribution Margin $/trip	203,400	657,600

If we not obtain the ratio of contribution margin to initial investment, we find that comparable figures are 1.2 for the 100,000 DWT vessel and 1.8 for the 300,000 DWT vessel.

It can be seen, therefore, that although the owner of the 300,000 DWT vessel enjoys only 25 percent of the total economies of scale, compared with 55 percent for the owner of the 100,000 DWT vessel, the former achieves a higher return on his investment. Furthermore, and as we have already intimated, the relative payload of the 300,000 DWT vessel is greater than three times that of the 100,000 DWT tanker, further enhancing the return on investment of the larger vessel.

These calculations have been carried out on the assumption that the vessels operate in the spot market. Overheads, inspection costs, taxes, and the risk premium for unemployment were not considered. It can be shown that the larger vessels yield a higher return on the owners' investment in the long run, than the smaller vessels, because the indirect costs do not increase proportionately with size (Zannetos, 1967). Such a long run analysis of return on investment, however, is beyond the scope of the present paper.

In order to test how well the proposed model explains the prevailing spot rates, we present in Figure 4 a comparison between actual and esti-

mated rates. The actual rates were obtained from Drewry (1) and represent the relevant rates for vessels of 100,000 to 174,999 DWT. Our estimates are obtained from the regression equation of Part 2 (b) of Table 2 for periods of high rates, and regression equation of Part 3 (b) of Table 2 for low rates. In both cases of estimated spot rates a vessel of 150,000 DWT is used.

As can be seen in Figure 4 the prediction of the model is quite respectable. Because Drewry's data are monthly averages of the transactions recorded and refer to a range of sizes (100,000 DWT to 174,999 DWT), the predictive power of our model has been adversely affected. Had we used actual data for 150,000 DWT vessels, we believe that the prediction would have been even better.

VII. CONCLUSIONS

The statistical model, despite certain inefficiencies arising from either unrefined or inadequate data, gave us very encouraging results in measuring the relative importance of the various quantifiable market characteristics in the formation of single-voyage freight rates.

The model enabled us to isolate the effect of vessel size on the formation of spot rates under various market conditions. This datum is of particular importance to oil exporters and shipowners alike. The results of our empirical investigation, are in complete agreement with theoretical predictions. Thus, during periods of capacity shortage and high freight rates, the owners enjoy a substantial proportion of the economies of scale that their large vessels realize, but during periods of excess capacity and low freight rates they have to concede most of these economies to the charterers, as compensation for the decreased flexibility and the increased risk of unemployment and underemployment

the charterers assume. However, the economies of scale are so large that, despite the substantial concessions to the charterers, the owners earn a higher return on their investment in large vessels than if they had invested in small ones. Even during periods of depressed rates the owners of large vessels lose less per unit of capacity than the owners of small vessels.

FIGURE 1 PROPORTION OF ECONOMIES OF SCALE ENJOYED BY OWNER: AUGUST 1973

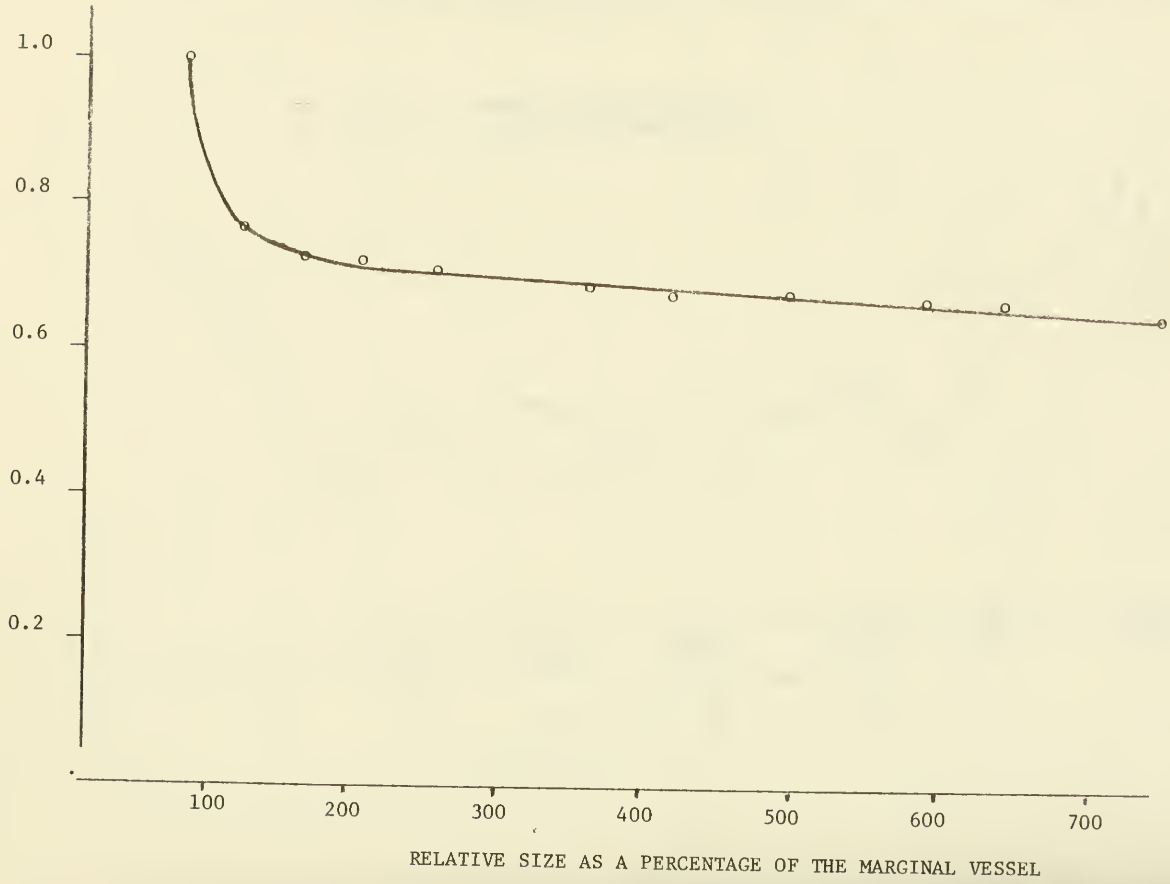

FIGURE 2 PROPORTION OF ECONOMIES OF SCALE ENJOYED BY OWNER: MAY 1975

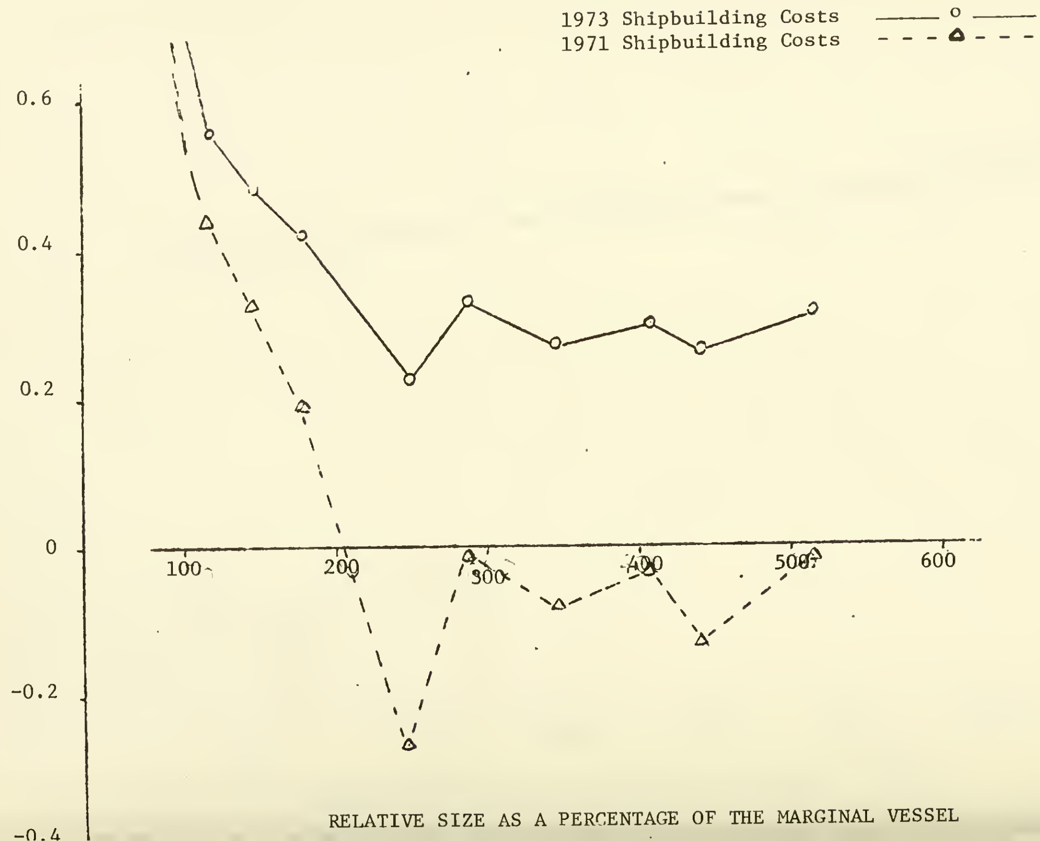

FIGURE 3 PROPORTION OF ECONOMIES OF SCALE ENJOYED BY OWNER: OCTOBER 1974

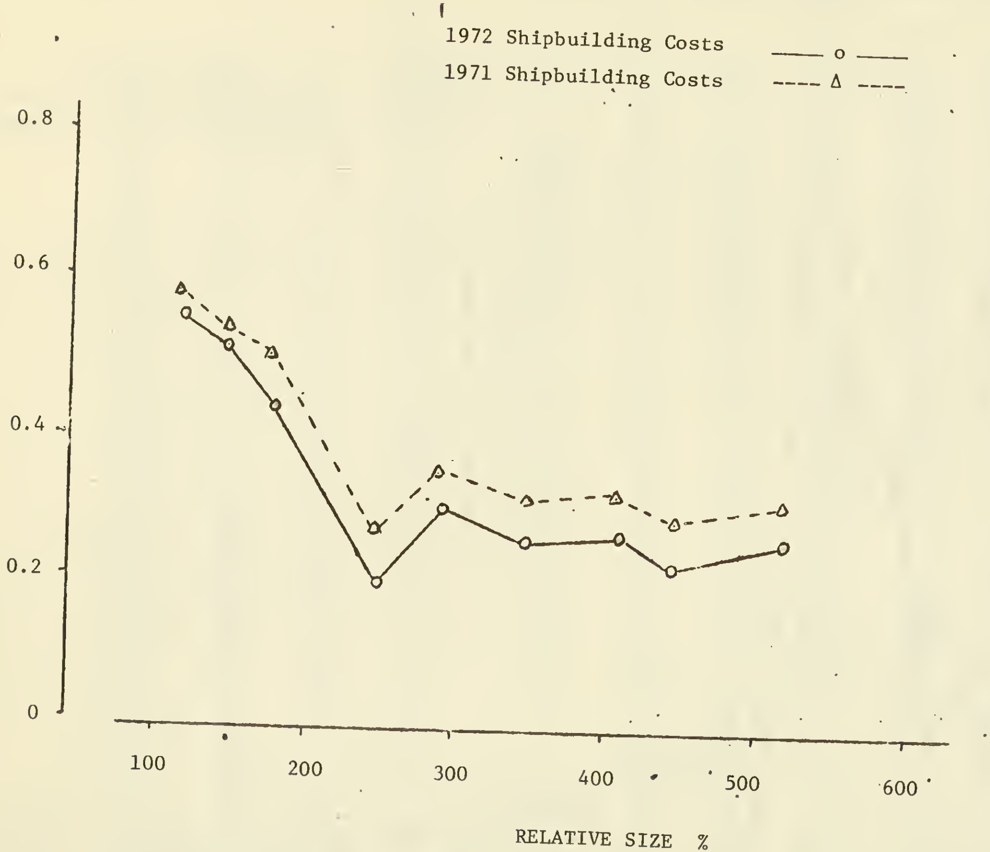

FIGURE 4 SINGLE VOYAGE FREIGHT RATES

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